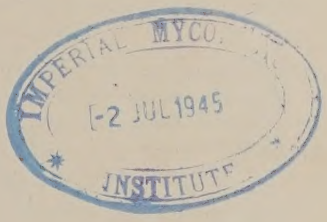
CIRCULAR BULLETIN 139 (Second Revision) JANUARY 1945

TOMATO DISEASES *in Michigan*

By M. C. STRONG



MICHIGAN STATE COLLEGE
AGRICULTURAL EXPERIMENT STATION
SECTION OF BOTANY
EAST LANSING

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Issued February 1932
First Revision, January 1938
Second Revision, January 1945

1 2 APR 1945

Tomato Diseases in Michigan

By M. C. STRONG

Because of its high vitamin content and dietary value, the tomato is an important crop wherever it is grown. It is an excellent source of vitamin C and also furnishes vitamins A, B_1, and G.

In 1942, 6,000 acres of market tomatoes and an equal acreage of canning tomatoes were planted in Michigan. This amounts to an increase of approximately 4,400 acres in the last 6 years, and is exclusive of home gardens which have also greatly increased in number in the last year. The total value of the 1942 crop of tomatoes produced in this state was $2,955,000.*

About 40 tomato diseases occur in Michigan. Some of these are of major importance and others are less so, but they are all factors which reduce the maximum of tomato production, and waste labor both in commercial plantings and in the home garden.

The purpose of this bulletin is to describe the common diseases of tomato and to discuss their control so that growers may be able to identify and combat or prevent them. In preparation, all the available pertinent information and publications of this and other experiment stations have been consulted. Acknowledgment is made of the use of such information, but the sources are too numerous to be cited here. No attempt is made here to discuss the proper culture of tomatoes. For this information the grower is referred to Michigan Agricultural Experiment Station Special Bulletin S-131, "Tomato Growing in Michigan".

CAUSES OF PLANT DISEASES

Plant diseases are of two general types, parasitic and non-parasitic. The parasitic diseases are caused by some living organism which grows and feeds on the plant, thereby making the natural development of the plant impossible. Non-parasitic diseases are caused by unfavorable environmental conditions, such as drought or temperatures near the freezing point, and nutrient deficiencies or excesses in the soil. According to the nature of the causal agents, parasitic diseases may be classified as fungous, bacterial, and virus diseases.

*From U. S. Dept. of Agriculture *Agricultural Statistics, 1943.*

Fungi, Bacteria, and Viruses

Fungi and bacteria are microscopic plants which have no green coloring matter and, therefore, cannot manufacture their own food. They have to obtain their food from other living organisms, called hosts, in or upon which they grow; or they may feed on dead organic material. The parasitic species of these microscopic plants produce digestive ferments or enzymes which dissolve the tissues or the organic contents of the hosts to make them available as food. This process causes changes in the hosts which we may observe even when we cannot see the organism itself. These changes in the host plant are called symptoms, and growers should learn to recognize them.

Most fungi consist of microscopic, slender, branching, colorless or colored threads. After a fungus has grown for awhile and has stored up some food, it usually reproduces itself by means of minute bodies, called spores, which may be transported by wind, water, insects, or by tillage implements. These spores are capable of germinating and producing a new plant. Sometimes a week or 10 days is long enough for the production of a new crop of spores which increases considerably the possibilities of the spread of the fungus to other hosts.

Bacteria are much like fungi in their feeding habits, but are smaller in size. Those that infect tomatoes are rod-shaped. They reproduce by

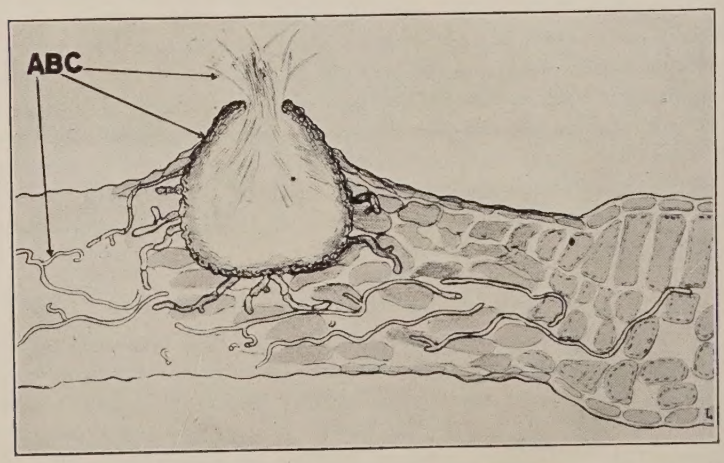

Fig. 1. Drawing of a section through a tomato leaf infected with Septoria lycopersici showing: a—fungus threads, b—fruiting body or spore case of the fungus, c—long, needle-shaped spores. Notice that the diseased portion of the leaf is thinner than the healthy part (shown at the right) because of the collapse of the infected cells. The picture is greatly enlarged. At this magnification the tomato leaflet would be nearly 8 feet across. (Drawing by L. J. Krakover.)

dividing into two equal parts, and as it requires only about half an hour for these organisms to mature so that they may divide again, several million bacteria may result from a single one in 24 hours.

Plants affected with bacterial diseases usually exude a slimy substance containing millions of bacteria, or the diseased tissues may become exposed by breaking open so that the germs can be spread to other plants by insects, by pruning tools, or by the splashing of rain.

The causal agents of the virus diseases are so small that their nature has not been determined by microscopic study. However, a great deal is known about their characteristics. They are believed by many investigators to be alive and able to reproduce themselves, because a very small amount of juice from an infected plant transferred to a healthy plant may cause the latter to become diseased also. The viruses causing tomato diseases are very infectious and are easily transmitted from diseased to healthy plants.

The viruses are not usually specific to a particular host, but may infect a wide range of hosts. For example, the spotted wilt virus is known to infect 40 species of plants belonging to 14 plant families. A virus often causes different symptoms on different hosts. The virus that causes cucumber mosaic, characterized by crinkling and mottling of the leaves, produces elongation and distortion of tomato leaves, and on the tomato the disease is known as "fern leaf" mosaic. Sometimes two different viruses may infect a host plant and cause symptoms entirely different from either virus alone. For example, the latent potato virus which produces no symptoms on potato, causes a mottling on tomato. The common tobacco mosaic virus produces mosaic on both tobacco and tomato. But when the latent potato virus and the tobacco mosaic virus are both present in tomato, the resulting disease is called "streak" and the symptoms are different from either mosaic or mottle. It is evident from these examples that the virus diseases represent a very complex group that is difficult to study.

PARASITIC DISEASES

Damping-off

This is a universal disease of seedlings. The stems of affected plants rot just above the surface of the soil so that the portion above usually topples over. This trouble is caused by several soil fungi. Rhizoctonia, Pythium, and Fusarium, which are able to infect the tender young stems of many other kinds of plants as well as tomato. These fungi are usually present in the soil, living on dead plant material there, and when the proper conditions are offered, they are able to infect the living seedlings.

Over-crowding and excessive watering of the seedbed are two factors which promote this trouble. Plant seeds thinly in rows rather than broadcast and avoid keeping the seedbed too wet.

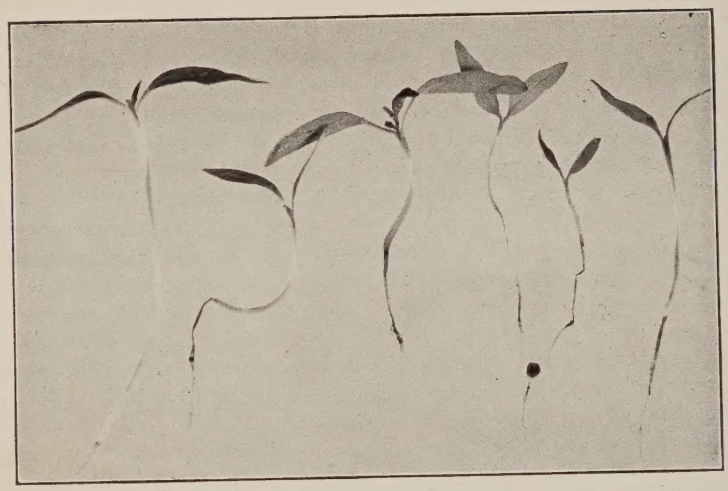

Fig. 2. Damping-off of tomato seedlings. The plant on the left is healthy. Note shriveled stems of the infected seedlings.

Sterilization of the seedbed with steam (see general discussion of control measures) when possible is the most certain control measure. Formaldehyde has been used successfully to combat this disease. The formaldehyde dust (6-percent formaldehyde) should be mixed with the top 3 inches of soil in the seedbed at the rate of 1½ oz. per square foot; the seed may be sown immediately. The soil must be watered thoroughly. This treatment slightly delays the emergence of the seedlings, but they grow rapidly so that at transplanting time they are sufficiently large.

Disinfection of the soil with formaldehyde dust must not be confused with dust treatments that are applied to the seeds. Dusting seeds with a fungicidal chemical before planting is also an effective method of controlling damping-off. Many mercury dusts are not recommended for tomatoes because they frequently cause injury to the seedlings. However, Ceresan has shown very promising results. Of the copper dusts, either red oxide of copper or copper carbonate are satisfactory. Copper is very toxic to most fungi, and the seedlings will be protected for a time, probably until they are too old to be affected by this disease. Zinc oxide also has been recommended as a dust for seed treatment, but is usually not so effective as a copper dust.

Dusting may be accomplished by placing the seed in a fruit jar with the chemical (at the rate specified by the manufacturer) and shaking

until the seeds are well coated with dust. The container should not be more than half full for best results.

Another method of preventing damping-off is the use of sand cultures for growing seedlings. Sand as free from silt and loam as possible is obtained from a sand pit, lake, or river. The sand is washed in several changes of hot water (160° F. or above) and placed in clean flats to a depth of about two inches. For each square foot of sand surface, dissolve ½ teaspoonful of potassium nitrate (saltpeter) in ½ cup of water and sprinkle over the sand. Sow the seeds and cover to the proper depth with more washed sand. Keep the surface of the sand moist by occasional watering with clean water. Do not add soil to the culture. If the seeds require more cover after sprouting, use more washed sand. Fungus control in the sand culture depends on the absence of any organic matter on which the fungus may grow. The sand culture produces healthy seedlings which are easily handled in transplanting as the sand may be washed off without injury to the roots. No steam stertilization of the sand is required—only the washing in several changes of hot water—and no seed treatment. The sand may be used over again after being rewashed in hot water.

Fusarium Wilt

Fusarium wilt is widely distributed in the tomato-growing regions of the United States, being very serious in the southern states and present in the northern states every season. In Michigan, greater losses are sustained in abnormally hot seasons. Fusarium wilt is also a common disease of greenhouse tomatoes.

This disease is caused by a fungus, *Fusarium bulbigenum* var. *lycopersici*. It is often called "yellows" because one of the most conspicuous symptoms is a yellowing of the leaves before they die and shrivel up. Yellowing and wilting of the foliage begins with the lower leaves and proceeds upward. Rolling of the leaves is not a symptom of this trouble. Many varieties of tomato show leaf roll on perfectly healthy plants during periods of wet weather.

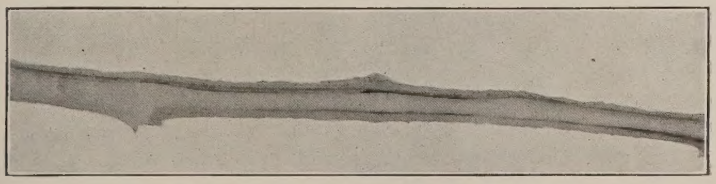

Fig. 3. Longitudinal section of stem of tomato plant infected with Fusarium wilt. Note dark streaks in the woody tissue.

The plant may be attacked at any stage of its growth. When a plant becomes infected in the seedbed, it usually is stunted and entirely killed before the fruiting stage, but when older plants are attacked, they may be able to mature a few fruits before being completely killed. Sometimes infected plants do not exhibit symptoms of the disease until fruiting begins, but the great demand for water during the formation of fruit usually results in the appearance of the symptoms. The setting of infected plants in the field is an important means of spreading the disease.

The wilt fungus lives in the soil and infects the plant by penetrating the small roots. Many roots are killed. The fungus grows through the water-conducting tubes up the stem, out into the leaves, into the fruit, and even into the seed. The presence of the fungus is always accompanied by a browning of the water-conducting tubes. This is a helpful diagnostic feature. If the stem is cut longitudinally, the brown streaks may easily be seen in the woody tissue.

Since the infection takes place in the soil, and the fungus is inside the plant, this disease cannot be controlled by any spray or dust treatment. The control lies in the destruction of the fungus in the soil before the plant becomes infected. This is possible in seedbeds and greenhouses by steam sterilization of the soil (see general discussion of control measures). This method of control is not applicable in the field, however. A suitable rotation of crops will reduce the infestation of the soil by this fungus, but since the fungus can live saprophytically in the soil for several years, the longer the land is without tomatoes the greater the value of the rotation. The fungus has been known to persist in the soil for as long as 10 years. In the case of badly infested soil when such rotation is impossible, varieties of tomatoes resistant to the disease should be grown.

Several varieties of tomato that are resistant to Fusarium wilt have been developed in various parts of the country. Many of these are not immune but produce a satisfactory crop in spite of the disease. Among the varieties best suited to our relatively short growing season are Prichard and a fusarium-wilt-resistant strain of John Baer. Marglobe and Rutgers are wilt-resistant varieties of excellent quality but are a little late except for the most southern part of the state. Pan America is a new variety resulting from a cross between Marglobe and *Lycopersicon pimpinellifolium,* a small currant type. Pan America possesses high wilt resistance, but is as late as Marglobe and produces smaller fruit. Michigan State Forcing is a wilt-resistant variety adapted to greenhouse culture.

Septoria Leaf Spot

Leaf spot, sometimes called leaf blight, is widely distributed in the tomato-growing regions east of the Rocky Mountains, being most destructive in wet seasons when the temperatures range from 60° to

Fig. 4. Septoria leaf spot on leaves and stems. The inset in the upper left-hand corner is an enlargement of a portion of the leaf immediately below showing the tiny black fruiting bodies on some of the larger spots.

80° F. Hot, dry weather during the growing season is not favorable for the development or spread of the disease.

The first symptoms of this trouble are small, grey spots with a black border. Later the entire leaf dies and drops off the plant. The lower leaves are affected first, and as the disease advances upward the plant becomes progressively defoliated. This loss of leaves exposes the fruit to the sunlight so that it may scald. Leaf destruction also reduces the food-manufacturing power of the plant so that the half-matured fruits are not able to ripen normally. Such fruit usually lack firmness and often fail to develop a good red color but are orange colored. These secondary injuries of septoria blight greatly reduce the commercial grade of the fruit produced.

The fungus that causes this trouble is *Septoria lycopersici.* It produces spores in fruiting bodies which appear as small black dots on the grey spots on the leaves. The spores are released during rainy weather, and are splashed to other plants where they grow and produce the disease. For this reason, it is not a good practice to disturb or cultivate tomato plants while they are wet.

Septoria leaf spot may be controlled in the field by applications of a copper spray or dust. Plants in the seedbed should be sprayed with one of the fixed coppers or with a 2-2-50 bordeaux mixture. See the general discussion of control measures.

Sanitation will do much to prevent initial infection so that spraying may not be required. This fungus lives over winter on tomato trash in the field, and if this trash is destroyed the chances of infection the following spring are much less. In small tomato patches, the old vines should be carefully gathered up and burned. Where such a procedure is not practical, the old vines may be plowed under in the fall. It is important that the vines be completely covered. Cutting of the vines with a disc before plowing will help in burying them in the soil.

Septoria lycopersici also grows on several common weeds, horse nettle, night shade, ground cherry, and jimson weed, all of them, closely related to the tomato. If the disease is present on weeds near the seedbed or field, it may easily spread to the tomatoes. The removal and burning of such weeds will help prevent infection.

Early Blight

Early blight is a disease of wide distribution in the United States on both tomatoes and potatoes. This blight is caused by a fungus, *Alternaria solani,* which attacks leaves, stems, and fruit. On the leaf the fungus causes a brown, irregular spot with concentric rings of ridges about the edge giving a target-like appearance. Fruit infection occurs through stem scars, cracks, and wounds. Circular dark brown or black

sunken spots are formed which become covered with a black velvety growth. From these spots the fungus may penetrate into the pulpy interior and cause a rapid decay of the ripe fruit. The black velvety appearance on the surface is due to the formation of spores. These spores are blown by the wind and splashed by rain to other plants where they cause new infections.

In the seedbed, this parasite may cause a girdling of the young plants just above the surface of the soil. This form of infection is called "collar rot". Plants up to 3 weeks old are susceptible. Young plants with stem infections should not be set in the field as such plants usually break over in the wind. If infected plants must be used, it is advisable to set them deep enough so that new roots will form above the lesion on the stem.

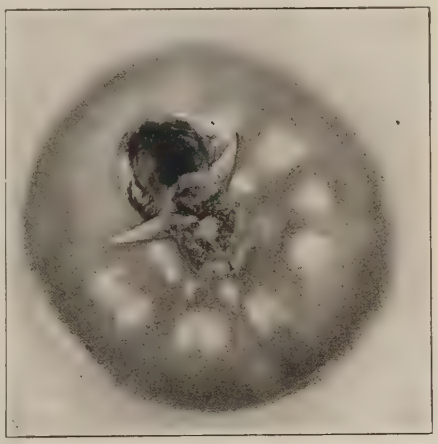

Fig. 5. Alternaria rot on tomato fruit.

Early blight is a cool weather disease that usually appears early in the growing season. Considerable damage may be done by this parasite in the seedbed if it is not controlled. If cool weather prevails throughout the growing season, blight continues to spread in the field and serious losses may result. Hot weather checks the spread of the disease.

In the southern states, a closely related fungus, *Alternaria tomato*, causes a similar disease except that the green fruit becomes spotted with many small, circular, sunken spots. This fruit spot is called "nail-head spot" or "rust".

The early blight fungus lives over winter in the soil, and on trash in the field and seedbed. The control measures recommended are sanitation and the application of a copper spray or dust. In the seedbed, a fixed copper spray or a 2-2-50 bordeaux mixture should be applied as soon as the second true leaves appear, and should be repeated at intervals of about 10 days depending on the growth of the plants. Because of its injurious effect in increasing the transpiration rate, bordeaux mixture should not be used later than 7 days previous to the date of transplanting. See the general discussion of control measures.

Fig. 6. Collar rot. The photograph on the right is natural size showing a constricted lesion at the ground level and a secondary lesion above. The photograph at the left is enlarged X3 to show the concentric zoning in the secondary lesion.

Fig. 7. Early blight of tomato. Notice the concentric zones of the dark spots.

Phoma Spot and Rot

The fungus *Phoma destructiva* causes a leaf spot and fruit rot of tomato that resembles and is sometimes confused with early blight and *Alternaria* rot. The parasite has been reported present in most

tomato-growing regions and is very destructive to winter-grown tomatoes in the south with resulting losses in transit and storage.

Cool, wet seasons favor the development and spread of this disease. During warm, dry seasons it is seldom prevalent.

Irregular, black or dark brown spots are produced on the foliage. On the fruit, infection takes place only through wounds such as stem scars, cracks and mechanical injuries. Both green and ripe fruits may be attacked, but the rot progresses much more rapidly in ripe fruit. Infection is first apparent as a small, sunken, water-soaked spot which becomes black and leathery as it increases in size. The rot penetrates into the pulp, and the underlying tissues become brown or black but remain firm. After about 3 weeks black, pimple-like pycnidia containing spores are formed in the center of the spot. The dry crust-like center of the spot often cracks, allowing the entrance of other fungi and bacteria that hasten the rotting of the fruit.

Control measures are seed disinfection, crop rotation and the application of copper sprays or dusts during cool, wet seasons. Fruit showing spots should not be packed.

Anthracnose

Anthracnose is present in most of the tomato-growing regions of the United States, but is more serious in the northern sections than in the southern. The disease is caused by *Colletotrichum phomoides*, a fungus which infects ripe fruit, causing a rot which may result in considerable losses on late fruits that are allowed to ripen on the vine for canning purposes. In Michigan, anthracnose does not usually appear until late in August or in September.

In the early stages, anthracnose is characterized by small, circular, sunken spots of about the same color or slightly darker than the surrounding tissue. The spots increase in size to an inch or more in diameter and penetrate deeply into the fruit. Cream-colored, pink or brown spore masses are formed on the center of the diseased spot. These spore masses may be arranged irregularly or in concentric rings. With age, the center of the spot usually becomes dark brown or black.

Warm, wet weather favors the development and spread of anthracnose. Since the causal fungus overwinters in the soil, a rotation of crops is advisable as a control measure. Frequent picking of all the ripe fruit has been recommended to reduce losses from this disease.

In the last 2 years Fermate (ferric dimethyl dithio carbamate) has been placed on the market as a fungicide. While testing Fermate as a substitute for copper in controlling the blight diseases of tomato, workers in New York and Ohio found that it appeared to have beneficial effects in reducing losses from anthracnose. Fermate sprays are

Fig. 8. Tomato anthracnose.

now being carefully tested at several agricultural experiment stations to determine the value of this fungicide in controlling anthracnose, and the best manner of application. This work is still in the experimental stage and definite recommendations cannot be made at this time.

Late Blight

Late blight is common in the southeastern and gulf states, causing small losses. In the northern states it usually does not appear until the latter part of July. The seriousness of the infection depends upon weather conditions. Temperatures between 50° and 80° F. favor the development of the fungus. In seasons that are abnormally cool and wet, this blight is likely to assume very dangerous proportions. Epidemics of late blight have caused serious losses in the field in California, Texas, Virginia, Massachusetts, Pennsylvania, and Ohio. The disease sometimes occurs in greenhouses if the temperature is kept too low.

This disease is believed to be identical with the late blight of potato caused by *Phytophthora infestans*. This fungus causes dark, water-soaked areas on leaves and stems. A badly infected plant resembles one killed by frost. On the under side of the leaf, a white, downy growth appears which bears the spores of the fungus. These spores spread the disease to other plants. On the fruit, a rot is produced usually beginning near the stem end, and spreading around the surface of the fruit faster than it penetrates into the interior. The rotted portion remains firm, but is discolored, and the skin becomes wrinkled. The rot develops rapidly, and soon involves the whole fruit.

Rotting of fruit is often serious in the transportation and marketing of tomatoes. Fruits picked from infected plants often show no evidence of infection at the time of packing, but develop rot during transit.

Though late blight is of little importance in growing seasons when normal temperature and moisture conditions prevail, it must be recognized as a potential danger to the tomato crop. Provided temperature and moisture conditions are favorable for its development, the fungus

Fig. 9. Phytophthora rot on greenhouse tomatoes. The whole lower cluster of fruit is affected as well as the leaf. Notice the white downy growth on the third and fourth fruit.

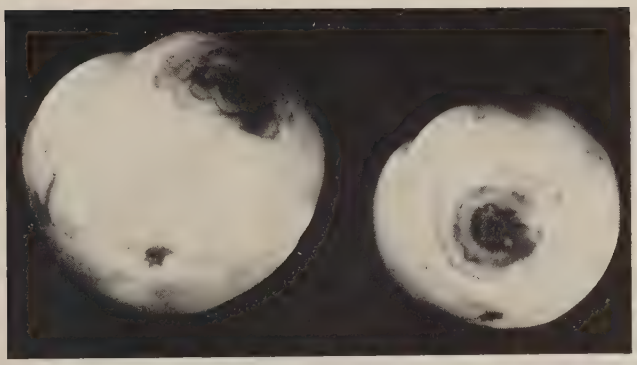

Fig. 10. Buckeye rot. The concentric markings are reddish brown.

is able to kill entire plants rapidly and to spread over whole fields. In the field late blight may be effectively controlled by spraying with a 4-2-50 bordeaux mixture at intervals of a week or 10 days. In the greenhouse this trouble may be controlled by keeping the temperature above 75° F.

Buckeye Rot

Buckeye rot is a disease of tomato caused by the fungus *Phytophthora terrestris* which is a common inhabitant of the soil. Either green or ripe fruits are attacked and usually those in contact with the soil, although heavy rains may splash the fungus onto fruits above. This fungus can penetrate the unbroken skin of the fruit, and depends upon periods of warm, wet weather for its development.

The first symptom is a greyish-green or brown water-soaked spot on the side of the fruit next to the soil. The spots enlarge rapidly often covering half the fruit, and usually developing a characteristic zonate marking of chestnut brown. Green fruits remain firm but become soft as they ripen. The same fungus also affects eggplants and peppers.

Tomatoes should not be planted for at least 3 years on soil where this disease has occurred. Good drainage will help reduce losses from this source. In small plantings, staking of the plants to keep the fruit off the ground is recommended. A straw mulch may also be used to keep fruit off the ground, and prevent splashing of soil onto the fruit.

Leaf Mold

Leaf mold is a serious disease of greenhouse tomatoes, but is seldom important in the field. It is caused by a fungus, *Cladosporium fulvum,* which attacks the lower side of the leaf, making a velvety spot,

olivaceous to purple in color. Yellow discolorations appear on the upper side of the leaf above the infected area. On the velvety spots, spores are abundantly produced which are blown and splashed to other plants where they set up new infections.

Leaf mold reduces the efficiency of the leaves in manufacturing food for the plant, and thus reduces the yield of fruit. The fungus is also able to infect the blossoms with the result that the blossoms fail to set fruit. Once the fruit is set, it is usually free from attack by this parasite.

Fig. 11. Tomato leaf showing Cladosporium leaf mold on the under side. (Photograph by W. K. Makemson.)

This disease is most serious in damp, cloudy weather when the humidity is high, and also in bright sunny weather if ventilation is inadequate. On a bright day, the rapid transpiration of moisture from the leaves increases the humidity of the air close to the leaves, making ideal conditions for the growth of the fungus. The development and spread of leaf mold depend entirely on humidity. If the humidity can be controlled by proper ventilation and circulation of air in the greenhouse, the disease will be controlled also. Forced ventilation by means of electric fans has given good control in houses containing a high percentage of infected plants. Overcrowding of plants is to be avoided, and pruning of the lower leaves may be resorted to in order to increase air circulation. Surface irrigation should be employed rather than over-head sprinkling, when the disease is present in the greenhouse.

In spring and fall, it is necessary to heat the greenhouse at night to avoid a considerable drop in temperature from the high daytime temperature. This prevents the condensation of moisture on the leaves of the plant, and helps control leaf mold.

A distribution of the heating pipes throughout the greenhouse rather than placing them all on the side walls, has helped some growers to control leaf mold. One steam pipe is placed near the ground between every other row of plants. The alternate space between rows is left slightly wider and is used as the runway. This arrangement of the pipes gives a more uniform distribution of temperature, and prevents condensation of moisture on the lower leaves of the plant.

Many kinds of spray have been tried by investigators in an attempt to control this disease. Many treatments have proved ineffective, and some have been injurious to the foliage or have left an undesirable residue on the fruit. A 0.5 percent colloidal sulfur spray has given good control but is expensive. Sulfur vapor is probably the best fumigant that can be used. Because of the danger of burning foliage with sulfur vapor, it is recommended that complete fumigation of greenhouses be resorted to only when they are empty. In this way, the house may be freed from spores, and the infection of new plants largely prevented. The burning of sulfur at the rate of one pound to every 1,000 cubic feet of air space will give complete destruction of spores. Better results are obtained if several heaps of sulfur are burned simultaneously. Sulfur fumigation may result in damage to paint and metal because sulfuric acid is formed when sulfur vapor mixes with water. Fumigate when the greenhouse is empty and dry.

The spores of this fungus retain their viability from 8 to 10 months, even withstanding very low temperatures. After this length of time,

however, the spores lose their viability rather rapidly. Since the parasite is limited in host range to the tomato, a rotation period of one year should be sufficient to rid a greenhouse of this pest.

Fig. 12. Sclerotinia stem rot. Notice the cracking of the stem and the white fungus growth on the lower part of the lesion.

Three varieties of tomatoes resistant to leaf mold have been developed and are now available. Globelle is a pink-fruited variety, while Bay State and Vetomold are both red-fruited. None of these varieties is resistant to all strains of the fungus, but they may be useful in reducing losses from this disease.

***Sclerotinia* Stem Rot**

This disease is characterized by the formation of a brown canker on the stem near the surface of the soil. The canker may reach 6 or 8 inches in length, and is usually covered by a white, downy growth. The pithy interior of the stem becomes filled with small, hard, irregular, black bodies, the sclerotia or resting stage of the causal fungus. The top of the plant wilts due to a reduction of the water supply from the roots. The woody tissue in the cankered portion shreds apart allowing the sclerotia to become scattered.

The causal fungus, *Sclerotinia sclerotiorum*, is able to attack many host plants including lettuce, celery, carrots and some ornamental plants. The disease is not common on tomato but sometimes occurs in greenhouses where tomatoes follow lettuce or where lettuce is grown between the rows. The fungus enters the host plant only through wounds, in the case of tomatoes usually a wound produced by pruning.

Diseased plants should be removed and destroyed. Between crops the fungus may be eradicated from the soil either by steam sterilization or treatment with formaldehyde. (See section on soil sterilization.)

Bacterial Canker

Bacterial canker, sometimes called the Grand Rapids disease because it was first discovered in the vicinity of that city, is caused by *Phytomonas michiganensis,* and is the most serious bacterial disease in this state. Although there has not been a severe epidemic in this state since 1927, there was considerable loss sustained in 1935. During seasons of drouth, this trouble is not serious because the bacteria are spread by the splashing of rain. Both field and greenhouse tomatoes may be attacked and heavy losses may result under favorable conditions. Bacterial canker was first believed to be confined to the northern states but has appeared in many of the southern states.

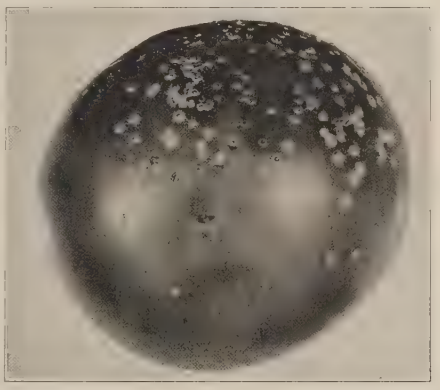

Fig. 13. Bacterial canker on tomato fruit, sometimes called "bird's-eye spot". Notice the white halo around every spot.

Bacterial canker is characterized by a progressive wilting from the lower leaves upward. The leaflets wilt and die while the petioles remain turgid. On the stems, yellowish streaks appear which later crack open forming cankers; from these cankers, the bacteria are spread by the splashing of rain to the fruit and to other plants. This organism produces a serious spotting on the fruit, making it unsalable. The spots on the fruit are small with a rough, brown center surrounded by a white halo, and usually occur in groups. This disfiguration of the fruit is called bird's-eye spot.

A plant may be attacked at any stage of growth. When a plant becomes infected in the seedling stage it may show no symptoms at the time of transplanting to the field, yet be entirely killed before any fruits are set. The bacteria spread through the water-conducting tissues to all parts of the plant. Open cankers are formed which allow the bacteria to be spread to healthy plants. When older plants are attacked, only the younger upper portions of the plant become infected, but more cankers will be formed to continue the external spotting of

the fruit and the spread of the disease to other plants. The fruit may also become internally infected by the migration of the bacteria through the water-conducting tissues into the fruit and even into the interior of the seeds. Such infected fruits are usually distorted and stunted, with a yellowish discoloration in the interior. Seeds from infected fruits may carry the bacteria either internally or on the seed coat, and be the source of infection for the next season. This organism is able to live in the soil over winter and infect tomato plants the following season.

Control of bacterial canker is very difficult because spray and dust treatments are not effective. Prevention of the disease must be the aim of the grower. Use only seed that is known to have come from healthy plants, free of this disease. Certified or inspected seed is now available from many seed companies. Soil contamination in seedbeds and greenhouses may be avoided by steam sterilization (see general discussion of control methods). In the field, soil contamination may be avoided by a rotation of crops. No other plant is known to be susceptible to this disease. A 4-year interval between tomato crops is believed to be sufficient to rid the soil of these bacteria. It is advisable to pull up and burn diseased plants as soon as they are discovered, to prevent the spread of the disease to other plants, and to prevent soil infection.

It has been found that fermentation of seed from canker-infected fruits will free the seed from contamination. The fruits are pulped and fermented with the juice at a temperature of 70° F. for 96 hours. The fermenting mass should be stirred twice daily. The seeds may then be extracted and dried.

Seeds extracted without fermentation may be freed from contamination with these bacteria by treating the seeds in an acetic acid soak for 24 hours at 70° F. Treat wet seed in an 0.8-percent solution of pure acetic acid in water (1 fluid oz. to 1 gallon water) or treat dry seed in a 0.6-percent solution of acetic acid in water (¾ oz. to 1 gallon water). Place the seeds loosely in a cloth bag and immerse them in the solution, stirring to insure wetting all the seeds. Treat no more than 1 pound of seed with each gallon of acetic acid solution. Dry the seeds after treatment.

Bacterial Wilt

Bacterial wilt, often called southern wilt, is very destructive in the southern states, but has never been known to occur in this state except on plants that were imported from the south.

The disease is caused by *Phytomonas solanacearum*. A plant affected with bacterial wilt resembles very closely one affected with Fusarium wilt. The discoloration in the woody part of the stem is black rather

than brown, however, and the cut stems exude a greyish slime. This exudate is characteristic of bacterial wilt, and is a sign that always distinguished this disease from Fusarium wilt.

Growers are advised against importing southern grown plants because of the danger of bringing in diseases which do not naturally occur here. At the time of shipping and setting in the field, the plants may show no evidence of disease, yet they may be infected and later develop the characteristic symptoms.

Bacterial Spot

Tomato bacterial spot, sometimes referred to as "scab" or "smallpox" is a common disease in Indiana, Illinois, and the neighboring states. It sometimes occurs in the southern part of this state, and is occasionally imported on plants from other localities. This disease is caused by *Phytomonas vesicatoria.*

On the fruit, a black, scab-like spot with an irregularly lobed edge surrounded by a water-soaked zone is produced. Several spots may enlarge and run together until a large scabby area results. This spot-

Fig. 14. Bacterial spot on tomato fruit. (Photograph by Ray Nelson.)

ting often causes considerable loss in marketable fruit. Spots are also produced on the leaves which resemble somewhat the spots caused by *Septoria lycopersici.*

The organism is carried over from season to season on the seed. To control the disease, seed disinfection is recommended. Soak the seed for 5 minutes in a 1 to 3,000 solution of corrosive sublimate and wash for 15 minutes in running water. Corrosive sublimate solution should not be put into metal containers and should be used only once. After one batch of seeds has been soaked, the germicidal action of the solution is greatly reduced and a fresh solution must be used for another lot of seeds. For ease in handling during the disinfection process, the seeds may be placed in a cloth bag which is large enough to allow for swelling. During the treatment the seeds should be stirred with a stick to remove air bubbles and insure the wetting of the seed coats. After the washing process the seeds should be spread out to dry in a well-ventilated place.

Mosaic

Mosaic is found wherever tomatoes are grown and may cause considerable losses in both field and greenhouse crops. The percentage of loss sustained depends on the time that infection takes place. If the plant is infected before the flowers develop, the fruit will be a total loss. Plants which do not become infected until late in the season may mature a few fruits before infection takes place.

Mosaic is a virus disease characterized by mottled areas of light and dark green on the leaves which are also crinkled and distorted. The fruit of infected plants is malformed and unmarketable.

The disease is very infectious and is easily spread by the laborers who cultivate and prune the plants, and pick the fruit. The small amount of plant juice that is transferred from one plant to another by a person merely brushing past the plants is sufficient to transfer the infection. Control depends on the removal and burning of infected plants as soon as discovered. In the greenhouse, the plants should be inspected before pruning is done, and infected plants be avoided until the end of the day's work, when they should be removed carefully so that they will not touch the adjacent plants. If many diseased plants are found, it is advisable to postpone pruning for a period of two weeks so that all infected plants will be showing definite symptoms before pruning is done. The virus diseases have an incubation period of about 2 weeks; that is, there is a period of about 14 days between the time the plant is inoculated and when the symptoms appear. During the incubation period the virus is increasing in the plant and the juice of the

Fig. 15. Mottle. The leaf is yellow with only the veins showing green.

plant is infectious, although the symptoms of the disease are not yet evident.

The virus of tomato mosaic is identical with that of common tobacco mosaic. It retains its viability for a considerable time even in dry plant tissue and may be transmitted from cigarets and chewing to-

bacco to tomatoes. The virus also lives for a long time (at least 70 days) in the soil. For this reason it is advisable to rotate tomatoes in the greenhouse with some other crop that is not susceptible.

This disease may be present in a number of cultivated plants and weeds from which it may be transferred to tomatoes by contact or by sucking insects. Some plants known to be susceptible to this virus are: snapdragon, beets, Swiss chard, carrot, buckwheat, mustard, pepper, turnip, larkspur, foxglove, morning glory, petunia, zinnia, eggplant, tobacco, potato, spinach, mullein, horse nettle, black night-shade, ground cherry, black henbane, phlox and green pod refugee bean.

The virus may be spread from plant to plant by several species of aphids, the mealy bug, and the tomato hornworm. Insects in the greenhouse should be controlled by frequent fumigation.

Fern Leaf

This disease occurs frequently on tomato, and is caused by the cucumber mosaic virus. The symptoms are dwarfing and yellowing of the plants, and spindling, narrow, distorted leaves with a fern-like appearance. The virus is spread from infected plants to healthy ones by handling and by aphids. Common weed hosts of this virus are milkweed, catnip, pokeweed and ground cherry. Control measures are careful removal and burning of diseased plants, and the control of aphids. Weed hosts growing near the greenhouse or seedbed should also be destroyed.

Mottle

This trouble is caused by the latent potato virus on tomato, and is characterized by irregular pale green areas between the veins, with little or no dwarfing of the plants. The virus is spread by contact. Workers handling potatoes previous to working with tomatoes may transmit the disease, but careful washing of the hands with soap and water will destroy the virus and prevent its transmission. Volunteer potato plants in the greenhouse may be a source of infection and should be removed.

Mottle by itself is not serious but it is dangerous because when combined with mosaic a very serious disease called "streak" is the result.

Streak

Streak or stripe as it is sometimes called, is a very serious virus disease common on tomatoes. It is a combination of two other virus diseases, mosaic and mottle, but is more serious than either.

The conspicuous symptoms of this trouble are black streaks on stems and petioles, and irregular black spots on the younger leaves. The

Fig. 16. Tomato streak on stem, leaf and fruit.

diseased fruit shows irregular, sunken, discolored areas and is unmarketable. The set of fruit is also greatly reduced.

Streak, like tomato mosaic, is very infectious and is spread by contact. Control measures are the careful removal and burning of diseased plants.

Spotted Wilt

Spotted wilt is a virus disease that is very serious in Australia, and has been reported in England, Canada, Oregon, Washington, California, Wisconsin, New York, and Michigan. The symptoms are bronzing of the leaves, a dark discoloration on stems and petioles, and conspicuous

Fig. 17. Spotted wilt of tomato on leaf.

circular spots on the fruit. Spotted wilt also occurs on dahlia, zinnia, aster, chrysanthemum, cineraria, potato, winter cherry, black nightshade, lupine, nasturtium, plantain, tobacco, eggplant, pepper, jimson weed, campanula, broad bean, and arum lily. The disease is spread by contact and by the black carnation thrips. Investigations carried on in England have shown that in greenhouses devoted to tomatoes alone, spotted wilt is seldom present, but in houses where ornamental plants are also grown, the occurrence of spotted wilt is frequent. Indications are that the virus is not seed-borne, and it does not remain viable more than 3 or 4 hours in the soil.

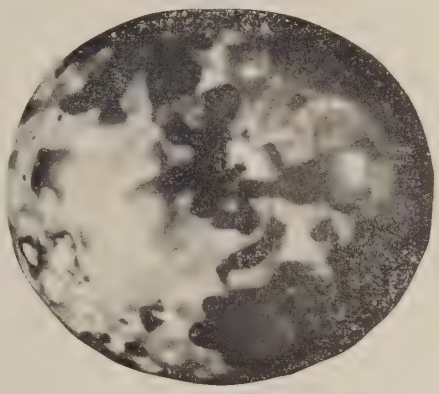

Fig. 18. Spotted wilt of tomato on ripe fruit, characterized by yellow circular markings.

Control measures are similar to those for other virus diseases. Avoid handling diseased plants when working with healthy plants. Pull out and destroy diseased plants. Control thrips by frequent fumigation with calcium cyanide. Avoid growing other plants which are hosts of this disease.

DISEASES CAUSED BY INSECTS AND NEMATODES

Cloudy or Cottony Spot

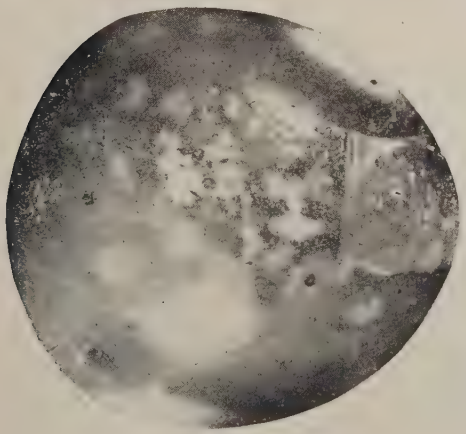

Fig. 19. Cloudy or cottony spots. The epidermis has been laid back to show the cottony clumps of white cells.

Tomatoes sometimes show irregular white spots, varying from those extremely small to half an inch in diameter, and occurring just below the skin. These blemishes may be few or many, but reduce the market value of the fruit. If the skin is peeled back, the spots are found to consist of a white cottony mass of cells.

This injury is the result of the feeding of stink bugs

on the fruit. The injury is not deep and no decay follows. However such fruit may be rejected by processing companies.

This trouble occurs sporadically and has not been frequently observed except in 1942 when it was reported to be of minor importance in some sections of the state.

Root Knot

Root knot is a disease of wide distribution in sandy soils in the southern states and a serious trouble in greenhouses in the northern states.

Root knot is caused by a microscopic nematode, or eel-worm, *Heterodera marioni*. These nematodes penetrate the roots of the plant, feed on the plant juices, and increase enormously in size. The mature females produce 200 to 400 eggs which may hatch within the root or externally, depending on the location of the mother nematode. The young nematodes may infect other plants. The root is stimulated to produce swellings or galls which are characteristic symptoms. Because the normal functions of the roots are interrupted by the invasion of these nematodes, the plants are stunted and sometimes killed.

Fig. 20. Tomato roots showing nematode galls (root knot).

Many different kinds of crops are attacked by this pest, and once it is introduced in a sandy soil, root knot is difficult to control. Growers are warned against the danger of importing this parasite from the southern states on tomato, strawberry, and other plants. Freezing will not free a soil of this pest. Under Michigan conditions, corn and the small grains, except buckwheat, appear to be free from attack by nematodes; and, by keeping infested soil in these crops for at least two seasons, the pest may be eventually starved out. It is necessary to keep the weeds out also, as many weeds are hosts.

In the greenhouse, root knot is one of the most difficult diseases the grower has to control as the nematodes get beneath walks and walls where they are hard to reach. To control this pest, the grower must resort to thorough steam sterilization of the soil. See discussion in section on general control methods. The soil must be heated to 210° F. to a depth of one foot.

The use of Chloropicrin (tear gas) as a soil disinfectant has also proved to be an effective agent in controlling the root knot nematode.

NON-PARASITIC DISEASES

Blossom-end Rot

This trouble, sometimes called "black rot," "dry rot," or "point rot," is one of the most common of the non-parasitic diseases, and frequently results in considerable losses, both in field and greenhouse crops.

The apical end of the fruit is affected. The first symptom is the appearance of a small, sunken spot about the remains of the style. The spot becomes dark colored and leathery, and as the fruit enlarges, the spot may increase in size until the apical half of the fruit is involved, so that the fruit appears much flattened. Fungi may later invade this spot and cause the fruit to rot, but they are not the cause of the disease.

Blossom-end rot is due to water deficiency during the development of the fruit. During periods of rapid transpiration from the leaves, the roots are frequently unable to supply sufficient water from the soil and a back flow of water from the fruit occurs causing the collapse and death of the tissue at the apical end of the fruit. The longer the duration of the water deficiency, the larger the amount of fruit tissue affected. Very young fruit is less likely to be affected because it has greater power to hold moisture. Older fruits have less imbibitional power and are more susceptible to this water loss. This trouble usually appears in the field during the latter part of July and August when rainfall is least abundant, but may be prevented by irrigation during periods of drouth.

Fertilizer treatments may have a direct effect on the production of blossom-end rot. Fertilizers high in nitrogen increase the suscepti-

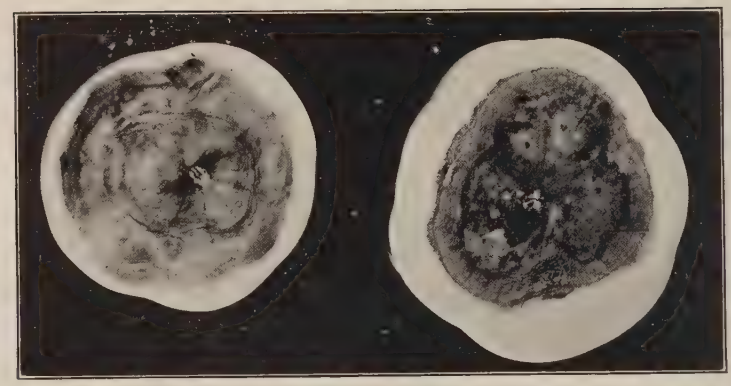

Fig. 21. Blossom-end rot of tomato fruit.

bility of the plant to this trouble while fertilizers high in phosphate seem to decrease the susceptibility to blossom-end rot.

There are also varietal differences in susceptibility to the disease, Marglobe being less susceptible than many varieties, and Bonny Best being more susceptible.

Blossom Drop

Blossom drop is a non-parasitic trouble caused by environmental conditions unfavorable to the fertilization of the flower. The production of pollen appears to be correlated with light and temperature. Conditions of high temperature and low humidity cause the styles to elongate abnormally, and before the pollen matures so that pollination cannot be effected. High temperatures also result in the failure of pollen grains to germinate. Temperatures ranging from 70° to 80° F. are most favorable for pollen germination.

Low fertility of the soil and insufficient soil moisture also affect blossoming. Nitrogen deficiency in the plant results in failure to produce normal ovules. Carbohydrate deficiency in the plant causes failure to produce germinable pollen. During periods of short daylight, carbohydrate deficiency is very likely to interfere with pollen formation. Supplementary illumination with Mazda light has been shown to increase the set of fruit during the poor light conditions of winter.

Although tomato flowers are usually self-pollinated, the parts of the flower are so arranged that the pollen does not easily reach the pistil. In the greenhouse where plants are not moved back and forth by the wind, it is necessary to resort to some artificial means of securing pollination such as shaking the vines.

Cat-face

This is the name given to tomato fruits misshapen by puckered blossom ends with irregular, leathery scars. The condition is due to the imperfect development of certain parts of the fruit, but the reason for such imperfect development is not understood. All varieties seem to be susceptible to this type of injury. The market value of such fruit is considerably decreased.

Cracking

Cracking of tomatoes usually follows after rainfall or irrigation and is due to the rapid absorption of water by certain tissues of the fruit. These cracks may radiate from the stem end and follow the interlocular walls, or be arranged concentrically about the shoulder of the fruit. Such cracks offer avenues of entrance to many fruit rotting fungi and bacteria.

The possibility of cracking increases with the age of the fruit. Picking mature green fruit prevents much cracking and produces more number one grade fruit than allowing to ripen on the vine. Frequent irrigation produces less cracking than irrigation at long intervals.

Blotchy Ripening

Blotchy ripening is a non-parasitic trouble of greenhouse tomatoes that is characterized by spots on the ovary wall which never ripen as the rest of the fruit matures. The vascular bundles beneath these spots are dark brown or black, and anatomical studies show the adjacent parenchyma cells to be ruptured and collapsed. This trouble is

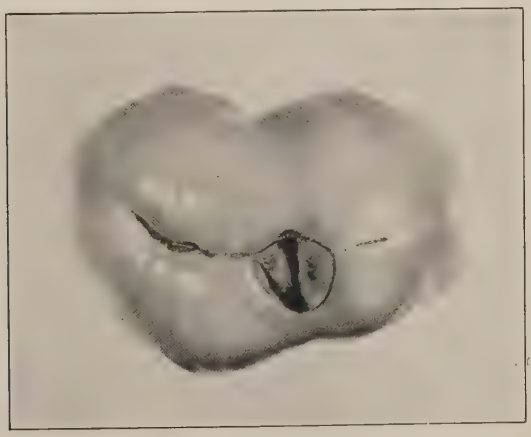

Fig. 22. Cat-face.

more severe in the spring crop of greenhouse tomatoes than in the fall or winter, and is seldom seen in the field crop. All varieties of tomatoes are susceptible.

The disease was believed to be a nutritional disorder, but recent studies indicate that it is the result of excessive transpiration occurring two to five days before ripening. During periods of excessive transpiration, the water loss from the leaves is greater than can be supplied from the roots, and water is removed from the fruit causing the collapse of certain cells. High nitrogen content of the soil, particularly early in the spring, produces larger plants which are more susceptible.

To avoid this trouble, plants should be grown slowly by watering sparingly during cloudy weather early in the spring. When the fruits begin to ripen, and light conditions improve, the amount of water given the plants may be increased. After May 15, large quantities are required. During periods of bright, sunny weather when greenhouse temperatures are high, excessive transpiration may be prevented by reducing the temperature and increasing the humidity. This may be accomplished by turning on the overhead irrigation several times daily. Shading may be advisable under some conditions, but should be used with caution if good fruit size is desired.

Tomato Pockets

Tomato pockets is the name applied to a defective condition of the fruit characterized by empty, hollow locules. Such fruits are light in weight and may appear flattened on the sides rather than round. The fruit may have entirely empty locules, or the placental tissues and seeds may be partially developed leaving an empty space only against the outer wall of the locule.

Many different names such as tomato puff, tomato pops, puffy tomato, and hollow tomato have been applied to this defect in different parts of the country, but the name tomato pockets has been proposed as being more descriptive of the condition.

The cause of this defect is not well understood, but various environmental conditions seem to favor its development. There appears to be a critical period early in the formation of fruit when unfavorable conditions have an important effect. Temperatures above 100° F. or below 60° F. as well as either excessive soil moisture or excessive drouth at the time of fertilization of the blossoms seem to induce it. Poor pollination is undoubtedly a factor in the production of pockets, but is not the only factor involved.

The proportion of affected fruits produced also depends on hereditary factors. It has been found that varieties, strains and individual plants

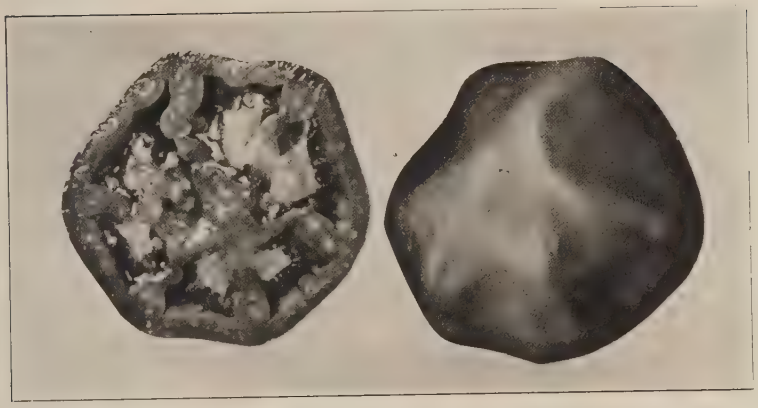

Fig. 23. Tomato pockets. The photograph on the right shows the flattened, irregular exterior of the fruit. The photograph on the left shows the interior of the same fruit with locules only partly filled.

within strains differ genetically with respect to susceptibility to develop pockets. Certain strains of Bonny Best, Earliana, Kanora, Marketeer, Stone, and Success show relatively small amounts of this defect, while some strains of Globe, and Marglobe may show relatively large amounts.

Sun Scald

If the foliage which ordinarily protects the green fruit is removed so that the fruit becomes exposed to intense, hot sunlight, a tough, white, sunken spot is produced on the exposed side. This type of injury is called sun scald. Varieties with thin foliage such as Break o' Day are often seriously affected by scald. This injury also often accompanies defoliation due to parasitic diseases, such as Septoria leaf spot, and Fusarium wilt. The lesions not only disfigure the fruit but offer avenues of entrance to rot-producing bacteria and fungi.

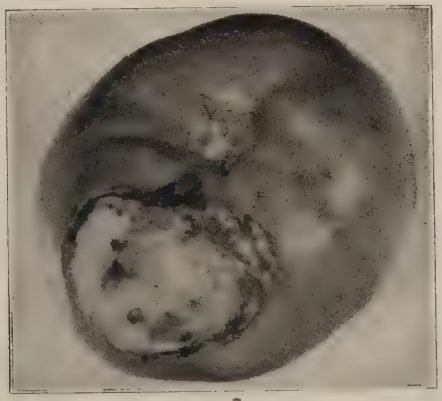

Fig. 24. Sun scald.

Leaf Roll

Tomato plants sometimes show an upward rolling of the older leaves. The symptom is very much like that of a virus disease of potato, and consequently is often the cause of alarm to growers. However, the rolling of tomato leaves is not caused by a virus infection, but is associated with periods of heavy rain and excessive soil moisture. The plant is uninjured and fruit production unaffected.

Walnut Wilt

The black walnut, *Juglans nigra,* has an antagonistic effect on many other plants that grow near it, and tomatoes are probably the most susceptible of all plants to this injury. Tomato plants growing adjacent to black walnut usually exhibit symptoms of wilting without discoloration in one or two months, and later may die.

The antagonistic effect of black walnut is caused by juglone, a toxic substance in the roots and shucks of this species. The cutting down of walnut trees will be of no immediate benefit in remedying the situation because the toxic effect will remain in the soil until all the roots have decayed and disappeared.

Avoid planting tomatoes within 50 feet of black walnut trees. The English walnut, *J. regia,* and butternut, *J. cinerea,* do not exhibit this injurious effect on tomatoes.

DISEASES OF UNDETERMINED ORIGIN

Ghost Spot

Ghost spot is the name given to a flat, white spot somewhat resembling bacterial canker infection on tomato fruit. No parasite has been found either in or on these white areas. The spot is circular and has a minute, brown speck in the center suggesting the appearance of an insect puncture. No insect has been found associated with this injury which is very superficial.

Ghost spot has been observed in Michigan and has been reported in other tomato-growing regions. It is not commercially important but may be alarming to growers because of its resemblance to the bird's-eye-spot stage of bacterial canker. Ghost spot is much larger and lacks the raised, tan-colored center with broken epidermis that characterizes the canker spot.

Fruit Pox

The disease known as fruit pox is characterized by small, circular, dark-colored, sunken spots or pits on the fruit. Sometimes the spots coalesce to form larger, irregular pits. The spots may occur anywhere

on the fruit but often are more abundant on the blossom end, or may appear in the form of streaks from the shoulder to the blossom end. These pits reduce the market value of the fruit, and offer entrance to various rot producing organisms.

This injury usually appears on full grown green fruit, and has been observed on both field and greenhouse plants. Its occurrence has been reported from several states. The cause and control of this trouble are at present unknown.

GENERAL DISCUSSION OF CONTROL MEASURES

When the life history of a parasite is known, it is usually possible to destroy it or prevent its spread. Parasitic tomato diseases may be seed or soil borne, transmitted from related plants or by all three of these methods. Diseases that are carried by the seed may be controlled by seed selection and by application of some of the various seed treatments described below. A few of the seed treatments also protect the seedlings from damping off which is a soil-borne disease.

Soil-borne diseases such as Fusarium wilt, damping off, root knot and bacterial canker may usually be controlled by soil sterilization or soil disinfection, and by a rotation of crops.

Diseases that are transmitted from related plants may be avoided by crop rotation, field and seedbed sanitation, and the destruction of certain weeds.

Seed Selection

Since some tomato diseases may be seed borne, the grower must be careful about the source of the seed he plants. It always pays to use disease-free seed, whether the grower saves the seed himself or buys it. Certified or inspected seed is now available to protect the grower from certain seed-borne diseases. If the grower wishes to save the seed himself, he must be familiar with the symptoms of disease and avoid saving seed from diseased plants.

Seed Treatment

Seed treatment is employed to accomplish two different results: (1) to disinfect the surface of the seed by destroying fungi such as *Alternaria* and *Phoma*, and the bacteria which cause canker and scab, and (2) to protect the seed against the soil-inhabiting fungi that cause damping off. Some seed treatments accomplish both these results, while others have only a single effect.

MERCURIC CHLORIDE

Seeds may be disinfected to free them from surface contamination by soaking in a 1–3,000 solution of mercuric chloride (bi-chloride of mercury or corrosive sublimate) for 5 minutes. This chemical may be purchased in the form of blue tablets or a white powder. One tablet dissolved in 3 pints of water makes a 1–3,000 solution. This is convenient for treating small quantities of seed. If the powdered form is used, dissolve ½ oz. in 11 gallons of water. The powder will dissolve more quickly if placed in 1 quart of boiling water, and then the remainder of the water is added cold. Either of these solutions will corrode metal and should consequently be mixed in earthenware or wooden containers. Both solutions are very poisonous, and must be handled and disposed of with care. Treat no more than 1 pound of dry seed in 1 gallon of solution, and use the solution only once. Wash seeds in running water for 15 minutes after treatment and spread out to dry. This treatment does not protect seeds against damping off, and they should receive a dust treatment before planting.

ETHYL MERCURY PHOSPHATE

Ethyl mercury phosphate (New Improved Ceresan) is an effective disinfectant for tomato seeds. A 1–1,200 solution (1 oz. in 9 gallons of water) is used. Seeds should be placed loosely in a cloth bag and soaked in the solution for 5 minutes after which the seed should be dried without rinsing. This treatment leaves some residue on the seed which will help combat damping off. This chemical is corrosive and poisonous and the precautions mentioned above must be observed.

COPPER SULFATE

Copper sulfate (blue vitriol) may also be used as a disinfectant for tomato seeds. Soak the seed for 1 hour in a solution containing 2 oz. of copper sulfate in 1 gallon of water. Drain off the solution and dry seed without rinsing. Treat no more than 1 pound of seed with 1 gallon of solution. The solution may be used again. This treatment leaves a residue on the seed which is also effective against damping off.

This chemical is corrosive and very poisonous, and therefore should be used only in earthenware or wooden containers, and must be handled and disposed of with caution.

HOT WATER TREATMENT

A hot water treatment may be applied to seed which will accomplish internal as well as external disinfection. The seeds are soaked in hot water at 122° F. for 25 minutes. The temperature must be carefully controlled with an accurate thermometer, otherwise germina-

tion of the seed will be reduced. After treatment, immerse seeds in cold water and spread out to dry. This treatment does not protect against damping off.

Cuprous Oxide

Cuprous oxide is used as a dust to prevent seed decay and damping off. For tomato seed, use 1½ level teaspoonfuls of dust to a pound of seed or 1½ pounds of dust to 100 pounds of seed. Mix in a tight container. Better mixing is obtained if the container is not more than half full. Screen off excess dust. Dusted seed may be stored safely if kept dry.

Zinc Oxide

Zinc oxide dust is also used to protect tomato seed against damping off. Use 2 level teaspoonfuls for every pound of seed or 1½ to 2 pounds of dust for 100 pounds of seed. Mix in a tight container until seeds are well coated, and screen off excess dust.

Semesan

Semesan dust is a commercial preparation containing 30 percent hydroxymercurichlorophenol, and is used for treating seeds to combat damping off. As a dust, it is applied at the rate of ¼ of a level teaspoonful to each pound of seed. They are mixed in a tight container until the seeds are coated with dust. When the excess dust is screened off, the seeds are ready to plant. Semesan may also be used in a solution of 1 oz. to 3 gallons of water. The wet treatment serves both as a surface disinfectant, and a protectant against damping off.

Acetic Acid

An acetic acid soak is used to disinfect seed contaminated with bacterial canker, and is described in the section on that disease.

Plant Selection

Use only healthy plants for setting. A diseased plant not only produces a poor yield, but may result in the infection of a whole field. It is sometimes difficult to distinguish between healthy and diseased plants in the early stages and the grower who does not produce his own plants should demand assurance that the plants he buys are free from disease. Southern-grown plants are often used for large acreages because they are cheap, but they may prove very expensive to the grower if they are not produced under careful supervision. Nematodes and Fusarium are common southern soil pests that may be introduced on southern-grown plants. Bacterial canker and the fungous leaf spots are frequently present on plants shipped in from the south.

Rotation of Crops

Soil-borne diseases may be controlled in the field by a rotation of crops. By growing crops which are not susceptible to infection, a parasite may eventually be starved out. Here it is necessary to know which crops to avoid (see special sections on diseases). As a general rule potatoes, peppers, or eggplants should not be grown in rotation with tomatoes. These plants are close relatives of the tomato and susceptible to many of the same diseases.

Soil Sterilization

In the greenhouse, soil-borne diseases may be controlled by steam sterilization of the soil which, if properly done, will completely destroy the soil-inhabiting parasites. Steam sterilization may be accomplished by means of a steam pan large enough to cover several square feet of area, yet not too large to be moved by workmen. The pan should be made of galvanized tin or iron, and should be about 12 inches deep, with sharp edges so that after the pan is inverted over the soil, it may be pushed down into the soil. This pan is attached to the steam boiler by means of a hose and steam is forced into the soil for about four hours. The soil should be in a loose, workable condition before steaming is attempted. The steam pan may be moved about until all the soil in the greenhouse has been sterilized. It is necessary that a temperature of 210° F. be maintained in the soil beneath the steam pan.

This method has several disadvantages. It requires much labor, the desired temperature may not be reached to a sufficient depth to assure complete sterilization of the soil, and there is danger of recontaminating the soil as the steam pan is moved about.

Another method of sterilizing soil with steam is by the use of 4-inch tile lines or 1½-inch iron pipe perforated on the lower side with ⅛-inch holes about a foot apart. The tile lines or pipe are buried in parallel rows in the soil and connected at one end to a steam line from the boiler. Tile lines laid 18 inches apart and 15 inches deep have proved more satisfactory than lines laid closer together and not so deep. Tile has an advantage over the iron pipe in that it does not rust, and consequently will last longer.

The installation of such a system for steam sterilization is expensive, but the results usually justify the cost. Much labor is saved and complete sterilization of a large area may be accomplished at one time with less danger of recontamination.

A sufficient pressure should be maintained in the boilers to produce a temperature of 210° F. in the soil. If the beds are covered with canvas or building paper, a higher temperature may be produced at

the surface of the soil than when the beds are left uncovered. The length of time required depends on the temperature reached. If the capacity of the boiler is great enough to produce a temperature of 210° F. in four hours that is long enough, but if lower temperatures are produced the time of steaming must be increased considerably.

When steam for sterilization is not available, soil may be sterilized by treating with a solution of formaldehyde, one pound formalin (40% formaldehyde) to 30 gallons of water. Spread the soil out in a layer six to eight inches deep and pour the solution on at the rate of one gallon to each square foot of soil. Cover tightly with canvas or burlap sacks for 48 hours. After this treatment, the soil must be allowed to air out for about two weeks before any seeds are planted. The soil should be well forked every day so that all the formaldehyde will be out of the soil before planting.

Flats, benches, soil containers and tools should also be sterilized with steam or formaldehyde to avoid recontamination of sterilized soil.

Chloropicrin (tear gas) has recently been used with some success as a soil disinfectant in destroying fungi, bacteria, and nematodes. This chemical is sold under various trade names, and is applied by means of a special device by which it is injected into the soil.

The soil should be worked to produce a loose, friable condition and should contain some moisture. Holes about 6 inches deep are made in the soil in rows 10 inches apart. The holes are spaced 10 inches apart in the row and are staggered to insure uniform distribution of the gas in the soil. After the chloropicrin is injected, soil is tamped down over it. When the treatment has been applied in all the holes, the surface of the soil is wet down about 1 inch to form a seal, and should be kept wet for 3 days. If possible, the soil should also be covered.

Plants may not be set in treated soil until all odor of the chloropicrin has disappeared which may require a week or longer depending on soil temperature.

This treatment should not be used where the fumes will reach plants, and the person who applies it is advised to wear a gas mask.

Sanitation

The grower should remember that with plant diseases, prevention is much easier and less expensive than control after the trouble has begun. General measures for the prevention of all parasitic diseases are sanitation, clean cultural practices, the use of disease-free seed, the use of non-infested soil for growing seedlings, the control of weeds, the immediate removal and burning of plants that are diseased, and the cleaning up and burning of dead plants and trash at the end of the growing season. Many parasites are able to live over winter on

dead plants on the ground. Such plants are sources of infection the following season. If these sources are destroyed, the chances of infection occurring the following year are much less. Old vines should be plowed under in the fall. In small fields, the old vines may be gathered and burned. Many weeds harbor plant diseases as well as insects which spread diseases. Horse nettle, ground cherry, jimson weed and nightshade growing in the vicinity of fields, seedbeds, and greenhouses should be destroyed.

Destruction of weeds or diseased plants does not mean merely pulling up or cutting off the plant and leaving it in the field or fence row, or piling up such plants on manure or compost heaps. Most fungi, and many bacteria and viruses are able to live for long periods of time on dead plants, and until burned these plants serve as sources of infection for healthy plants. Wind and insects may carry disease germs to healthy plants. Compost and manure containing diseased plants may serve to infest otherwise clean soil in seedbed or field.

Spraying and Dusting

Fungous diseases which are spread by wind-borne or rain-splashed spores may usually be controlled by protecting plants with fungicidal sprays or dusts. As the plant grows, new surfaces are exposed to infection so that such spray or dust treatments must be repeated every 10 or 14 days, sometimes more often, during the growing season.

The fungicide employed for spraying or dusting tomatoes is copper in one of its various forms. Bordeaux mixture, a combination of solutions of copper sulfate and lime in a 4-4-50 formula, has been in use for many years as a fungicidal spray. Recently, many other copper compounds called fixed or insoluble coppers, have been made available for use in sprays and dusts. These compounds include copper oxide, copper oxychloride, copper hydroxide, etc., and are sold under various trade names. They are not used in combination with lime, and so do not produce some of the deleterious effects sometimes associated with bordeaux mixture.

Tests of these copper compounds over a period of years to determine their efficacy in controlling the leaf blights indicate that many of them are able to increase fruit production and quality of fruit over that of untreated control plants in seasons when these diseases are severe. When these diseases are not prevalent, such spray and dust applications may be of doubtful value.

The first and most important spray application is made in the seedbed. As soon as the second true leaves appear, apply a 2-2-50 bordeaux mixture, or one of the fixed coppers at a concentration of 1 pound metallic copper per 50 gallons, and repeat at 10- or 14-day intervals

depending on the growth of the plants. If bordeaux mixture is used, do not apply later than 7 days previous to the date of transplanting as the lime in bordeaux increases the transpiration rate, and if applied any nearer to the transplanting date, may cause the wilting of the plants when they are set out.

In the field, a 4-2-50 bordeaux mixture, a fixed copper spray at a concentration of 1 pound metallic copper in 50 gallons, or a copper dust may be employed. The time of application depends upon the weather and the appearance of disease. It is advisable to withhold spray or dust applications until wet weather prevails. Then the plants should be protected. In either spraying or dusting, thoroughness of application is important. Cover both sides of all the leaves with a coating of spray or dust. Because it is difficult to cover the inner leaves during the latter part of the season, efficient power machinery is necessary for spraying or dusting. Spray when plants are dry, dust when they are wet. Spray or dust applications should be made when there is little or no wind.

Whether applications of a fungicidal spray or dust on tomatoes will prove to be a profitable investment depends upon several factors that cannot be predicted. In seasons when fungous leaf diseases are not prevalent, such spray or dust treatments may be a waste of labor and materials. When such diseases are prevalent and serious, fungicidal sprays or dusts effectively applied will increase production and quality of fruit. Whether increased production and quality of fruit will be of monetary value to the grower depends largely upon the price of tomatoes and the market served. If tomatoes are grown for a critical market as a processing company or any market where federal grades are enforced, an increase in fruit quality will command a better price. When tomatoes are scarce and the price is high, a moderate increase in production of fruit will bring a greater profit. When the price of tomatoes is low, profits are likely to be less than the cost of applying spray and dust treatments.

The grower is advised to be ready to spray or dust if necessary, but to time such treatments according to rainfall and the appearance of the diseases. Defoliating diseases are usually most severe after the fruit has begun to set, and spray or dust applications delayed until this time will provide effective control of these diseases if the early part of the season has been relatively dry.

Bordeaux Mixture

Bordeaux is made from copper sulfate (bluestone, blue vitriol), hydrated lime, and water. The first figure of a bordeaux formula always indicates the amount of copper sulfate in pounds, the second

figure the amount of hydrated lime in pounds, and the third figure the amount of water in gallons. A 4-2-50 bordeaux will require: 4 pounds copper sulfate, 2 pounds hydrated lime, and 50 gallons of water.

Bordeaux may be made in any quantity depending on the acreage of tomatoes to be treated, but this proportion of spray ingredients must be maintained. After the copper sulfate and lime are combined, the mixture does not keep long; therefore, the copper sulfate and lime are made up in separate solutions which keep indefinitely, and should not be mixed until just before the spray is to be applied. The usual procedure is to dissolve the copper sulfate in 25 gallons of water by suspending the copper sulfate crystals in a cloth sack, just below the surface of the water. The lime is made into a paste with a little water, and sufficient water is then added to make 25 gallons. These two solutions are mixed in equal proportions, and strained through a fine-mesh screen just before putting into the sprayer. Two pounds of calcium arsenate may be added for the control of flea beetles and tomato hornworms.

A pulverized or powdered form of copper sulfate that dissolves more rapidly is also available. This does not need to be made up into a stock solution. The required amount of copper sulfate powder is placed in the screen of the tank, and is dissolved by running water through it. With the agitator in operation, wash the lime paste into the tank, and add water to make the required amount. Calcium arsenate may also be added. Keep agitator in operation continuously after the copper sulfate is added.

Fixed Copper Sprays

The copper content of the various fixed copper compounds ranges from 25 to 85 percent. When used in sprays, these compounds are added in such concentration as to give 1 pound of metallic copper to 50 gallons of water. Consult the label for copper content of the material and calculate the amount to use. For example, if the copper content is 25 percent, use 4 pounds to 50 gallons; if the copper content is 50 percent, use 2 pounds. No lime is used in these sprays, but it is advisable to use a sticker (such as wheat flour at the rate of 4 pounds to 50 gallons) and a spreader. Calcium caseinate may be used as a spreader or one of the commercial compounds such as Orthex.

Dusting

Dusting is usually not so effective in controlling diseases as spraying, but many growers who have a power dusting machine and large acreages of tomatoes find a dust satisfactory. Dusting should always be done when the plants are wet with rain or dew and when there is little or no wind.

With power dusters, use two nozzles per row, and arrange them so as to direct the dust on each side of the row. For small fields, hand-operated dusters may be used.

Copper-lime Dust

The copper-lime dust recommended for tomatoes contains 80-percent spray lime and 20-percent monohydrated copper sulfate. When applied to damp foliage, this dust practically becomes a bordeaux mixture. It adheres well but like bordeaux has the deleterious effects of the excess lime.

Fixed Copper Dusts

The fixed copper compounds are also used in fungicidal dusts which may be purchased already mixed or may be mixed at home. These dust formulas usually specify a 5-percent metallic copper equivalent, that is 20 pounds of a compound containing 25-percent metallic copper. The other ingredients are wheat or soybean flour (15 percent) and enough finely ground talc to make a total of 100 percent by weight. Calcium arsenate is often included in these dust mixtures.

SUMMARY OF GENERAL CONTROL MEASURES

1. Use clean seed, and disease-free soil in the seedbed. Disinfect flats, sashes and boards that are to be used for seedbeds. Plant seed thinly in rows and do not water heavily. Spray the young plants in the seedbed with 2-2-50 bordeaux, or a fixed copper (at the rate of 1 pound metallic copper per 50 gallons of water).
2. Cultivate fields and gardens well to remove weeds. Destroy such weeds as jimson, ground cherry, nightshade and horse nettle in the vicinity of fields and gardens. Watch for diseased plants. Pull up and burn plants showing symptoms of mosaic as soon as discovered. If early or late blight or fungous leaf spots appear, spray with 4-2-50 bordeaux or a fixed copper (at the rate of 1 pound metallic copper per 50 gallons of water) at 10-day intervals until hot, dry weather prevails.
3. Clean up the field or garden when the crop is finished. Old vines should be plowed under in the fall or gathered up and burned. Do not allow plant trash to remain over winter on top of the ground.
4. Practice a rotation of crops in which tomatoes, potatoes, green peppers and eggplant do not follow one another.
5. In greenhouses, sterilize the soil before setting the plants. Control humidity by proper ventilation and control insects. Watch for the appearance of symptoms of mosaic and destroy diseased plants at once. Destroy weeds near the greenhouse, especially jimson weed, nightshade, ground cherry and horse nettle.

KEY TO SYMPTOMS OF COMMON TOMATO DISEASES

Stems shriveled at ground level with tops falling over (seedlings) ..... *Damping-off*

brown streaks in the woody tissue..... *Fusarium wilt*

black streaks in the woody tissue, slimy exudate when stem is cut ..... *Bacterial wilt*

yellow streaks, cracking open into cankers..... *Bacterial canker*

black streaks showing on surface..... *Streak*

greyish circular spots with black border, and sometimes black dots in center..... *Septoria leaf spot*

dark brown irregular depressed spots..... *Early blight*

dark brown cankers at ground level..... *Collar rot*

brown canker covered with downy white growth, pith filled with hard, black, irregular seed-like bodies..... *Sclerotinia stem rot*

Leaves mottled with light and dark green areas crinkled and distorted ..... *Mosaic*

mottled with pale green areas between the veins..... *Mottle*

narrow spindling distorted, with fern-like appearance.... *Fern leaf*

black irregular spotting on young leaves..... *Streak*

bronzing of young leaves..... *Spotted wilt*

turning yellow and wilting from lower portion of the plant progressively upward..... *Fusarium wilt*

wilting without yellowing..... *Bacterial wilt*

curling with velvety patches on under side, pale green or yellow above..... *Leaf mold*

greyish circular spots with dark border and sometimes black dots in center..... *Septoria leaf spot*

dark brown spots concentrically ringed..... *Early blight*

dark brown irregular spots ..... *Phoma spot*

dark water-soaked spots with white powdery growth on under side..... *Late blight*

leaflets wilting while petioles remain erect..... *Bacterial canker*

lower leaves rolling upward..... *Leaf roll*

wilting without discoloration on plants adjacent to black walnut trees..... *Walnut wilt*

Fruit dark shriveled spot on apical end..... *Blossom-end rot*

tough white spot on side..... *Sun scald*

hollow sterile locules..... *Pockets*

misshapen puckered with scar on apical end..... *Cat-face*

spots remaining green as the rest of the fruit ripens..... *Blotchy ripening*

cracks radiating from the stem end or arranged concentrically around shoulder..... *Cracking*

small circular sunken spots bearing cream colored to brown spore masses..... *Anthracnose*

misshapen with irregular sunken discolored brown spots... *Streak*

circular yellow markings..... *Spotted wilt*

dark brown scab-like spots, irregularly lobed with water soaked border..... *Bacterial spot*

small brownish crusty spots with white halo..... *Bacterial canker*

flat white spot with minute brown speck in center..... *Ghost spot*

circular sunken spots covered with black velvety growth... *Early blight*

black leathery sunken spot with black pimple-like pycnidia at the center..... *Phoma rot*

rapidly spreading rot, flesh firm, skin discolored and wrinkled, white growth on surface..... *Late blight*

white blotches just below the skin..... *Cloudy or Cottony spot*

large spots with zonate, brown markings..... *Buckeye rot*

small, circular, dark colored pits often coalescing to form larger depressed spots..... *Fruit pox*

Root: galls or swellings formed..... *Root knot*